

Site	Sample	Radiocarbon Age (years before present)	Context
MIS-495	Beta-165298	9910±40	Hearth feature
	Beta-165299	10,010±40	Hearth feature
NR-5	Beta-146117	9550±60	Wildfire? Sealed stratum
	Beta-146116	9640±300	Wildfire? Sealed stratum
Irwin Sluiceway	Beta-120696	9550±50	Hearth feature
	Beta-134677	10,050±70	Hearth feature
	Beta-131336	10,060±80	Hearth feature
Tuluq Hill	Beta-133394	7950±40	Hearth feature?
	Beta-122323	11,110±80	Isolated charcoal fragment
	Beta-159913	11,120±40	Hearth feature
	Beta-159915	11,160±40	Hearth feature
	Beta-122322	11,180±80	Hearth feature
	Beta-159914	11,200±40	Above hearth D
	Beta-133393	11,200±40	Hearth feature

Table 1. Radiocarbon dates for charcoal samples from early Noatak river basin sites.

Irwin Sluiceway site—and perhaps the distinctive projectile points it contained—was established. In the summer of 1998, Dennis Stanford, a Paleoindian expert from the Smithsonian, collaborated with Gal on testing the site, and the work uncovered a well-preserved fire hearth. Charcoal samples from the ancient campfire were radiocarbon dated to 10,000 years old. Altogether the site yielded about ten projectile points and a small amount of flaking debris; it appeared to be the remains of a single, briefly occupied hunting camp and lookout site.

During the same season, an NPS inventory project was conducted on Wrench Creek, another Noatak River tributary located in the western portion of the preserve. More spear points of the same style were found at a site named Tuluq Hill. The site yielded charcoal samples radiocarbon dated to between 11,100–11,200 years. Later work at the site in 1999 and 2001 yielded more dates in this time range and

confirmed that the charcoal was from a human-made hearth. We also found hundreds of pounds of flaking debris and more than 300 bifaces that were broken in the process of manufacture. These artifacts indicated that Tuluq Hill was an intensively used workshop site where people shaped chunks of chert into large bifaces, which were later made into tools such as projectile points or knives. We also recovered 64 worn out or broken projectile points that were discarded at the site in the process of re-arming spears.

The information from Tuluq Hill helped support an early age range for the Sluiceway technology, but a complex history of site use and relatively shallow stratigraphy at Tuluq Hill still left many questions unanswered. While the radiocarbon samples were spatially associated with Sluiceway-style artifacts, a concern at this site is whether people at other times in the past had also been drawn there for the same stone raw materials, thus resulting in a mix-

ture of artifacts from different time periods. Dated occurrences of these artifacts at less complicated sites would help refine their age range.

In addition to the new field discoveries, in 1999 more Sluiceway-like artifacts were “rediscovered” in old museum collections. One such discovery was a collection at the Haffenreffer Museum at Brown University from the NR-5 site. Located on the Noatak River in what is now Noatak Preserve, the site was identified and tested by Brown University archeologist Douglas Anderson in the early 1960s. It was briefly described in a 1972 article, but never given much attention in subsequent academic discussions since its age and relationship to recognized complexes was unclear. The collection contains about a dozen spear points, identical to those from the Irwin Sluiceway and Tuluq Hill sites, and a number of scraping and cutting tools, some of which replicated types seen at Tuluq Hill. We were now beginning to piece together components of the Sluiceway tool kit other than spear points. The collection also contained micro-



National Park Service photograph

Dozens of microblades—small, regularly shaped slivers of stone—could be detached from a single core and set in pieces of slotted bone, antler, or wood for use as cutting tools or projectile armaments.

blades—long, thin stone flakes that were mounted in slotted handles for use as cutting tools or projectile armaments. Microblades occur in some, but not all, of the earliest sites in Alaska and are interpreted to indicate cultural contacts with Siberia since this technology is seen much earlier there than it is in Alaska. It would be interesting to know if microblades were also part of the Sluiceway Complex tool kit, and we continue to pursue this question. They have since been found at Caribou Crossing and another Sluiceway Complex site on the Kelly River.

Other small collections housed at the University of Alaska Museum have also been found to contain Sluiceway-like artifacts, and additional new sites in Noatak National Preserve were discovered during surveys conducted between 1998 and 2002. Small scale testing at some of these sites has yielded radiocarbon dates. A revisit to NR-5 showed that the artifacts at the site where Anderson excavated occur in a discrete, sealed sediment layer, which has been dated to at least 9,550 years before present. A site near Natinakunit Pass (MIS-495) produced radiocarbon dates from a hearth feature of 9,910 and 10,010 years ago. In all, 19 sites with probable Sluiceway artifacts have been identified in northwestern interior Alaska, centered on the Noatak River Basin and the adjacent North Slope foothills. This is a substantial data set for looking at how some of the earliest known inhabitants of the region lived.

Test excavations at Caribou Crossing in 2002 unfortunately did not produce hearth remains nor samples suitable for radiocarbon dating, but an age estimate of about 10,000 years seems reasonable based on the



National Park Service photograph

Game trails crisscross the Caribou Crossing site. Despite its name, it is not clear which animals were hunted 10,000 years ago when this site was likely occupied.

radiocarbon dates accumulating at similar sites (Table 1). The fieldwork did yield surprising information about prehistoric technology, and hunting and storage tactics. The sheer number of projectiles points, 145 from two nearby localities, is unmatched in any Alaska site of any age. This dense accumulation, along with other lines of evidence, suggests it is unlikely to have resulted from a single occupation. People

were instead visiting this location repeatedly. They knew animal behavior well enough to predict their migrations through this narrow valley, probably using the natural topography to limit animal movement and kill large numbers of animals. Which prey species was hunted is still a mystery since no faunal remains (bones) are preserved at the site. It was almost surely a herd animal. Therefore bison, which still roamed northern Alaska at this time, as well as caribou, are good bets. The huge store of meat produced by group hunts like this probably meant that fairly substantial settlements were located nearby, in order to make use of these stores without having to transport them long distances.

The traces of past human activity—along with wildlife sightings, animal tracks, flora, etc.—are another of the rich layers of experience that make being in the wild places of an Alaska national park a memorable and enriching adventure. It is encouraging to think that these are still wild and beautiful places, and 11 millennia of human habita-

tion have only added to their allure. Our understanding of human history in this region is very much a work in progress. Because sites must be evaluated in terms of what they can teach us about the past, it is important to have good baseline knowledge about the sites we encounter and to understand how they relate to interesting research problems. In this sense, research and resource management must proceed simultaneously. Ten years ago, before the age of Sluiceway Complex artifacts were known, a site like MIS-495 would probably have received little attention. Seen from the perspective of a regional research question about hunters and with enough background knowledge to spur interest, the site was given a second look and as a result became one the few sites in the region radiocarbon dated to the early Holocene.

NOTE: Ages cited in this article are expressed in radiocarbon years before present (BP), which differ from actual calendar years. By convention “present” is established as 1950.

Radiocarbon dating is based on the principle that all living organisms—and thus the wood charcoal or bone deposited in archeological sites—contains a small proportion of radioactive carbon-14. Upon an organism’s death, carbon-14 is no longer ingested, and it begins to decay at a known rate (a half life of 5,730 years). The amount of carbon-14 remaining in an organic sample can then be used to calculate its age; however, the amount of carbon-14 in the atmosphere has fluctuated slightly over time.

The small errors compound with increasing age and can result in radiocarbon ages that are too young. For example, a radiocarbon date of 10,000 years BP is equivalent to about 11,400 calendar years, and a radiocarbon age of 11,200 years is equivalent to approximately 13,300 calendar years. To control for these discrepancies, scientists have documented the variation in atmospheric carbon-14 and developed calibration curves that can be used to convert radiocarbon ages into calendar years, known as calibrated radiocarbon years.

REFERENCES

- Anderson, D.D. 1972.
An Archaeological Survey of Noatak Drainage, Alaska.
Arctic Anthropology 9(1):66-117.
- Anderson, D.D. 1988.
Onion Portage: The Archaeology of a Stratified Site from the Kobuk River, Northwest Alaska.
Anthropological Papers of the University of Alaska 22(1-2).
- Hopkins, D.M., J.V. Mathews, C.E. Schweger, and S.B. Young (editors). 1982.
Paleoecology of Beringia. Academic Press, New York.
- Larsen, H. 1968.
Trail Creek: Final Report on the Excavation of Two Caves on Seward Peninsula, Alaska. Acta Arctic 15:7-79.
- Rasic, J.T. and R. Gal. 2000.
An Early Lithic Assemblage from the Tuluq Site, Northwest Alaska.
Current Research in the Pleistocene 17:66-68.
- Rasic, J.T. 2000.
Prehistoric Lithic Technology at the Tuluq Hill Site, Northwest Alaska. M.A. Thesis, Department of Anthropology, Washington State University.
- Reanier, R.E. 1995.
The Antiquity of Paleoindian Materials in Northern Alaska.
Arctic Anthropology 32(1):31-50.
- West, F.H. (editor). 1996.
American Beginnings: The Prehistory and Paleoecology of Beringia.
University of Chicago Press, Chicago.



High Latitude Marine Reserve Research in Glacier Bay National Park

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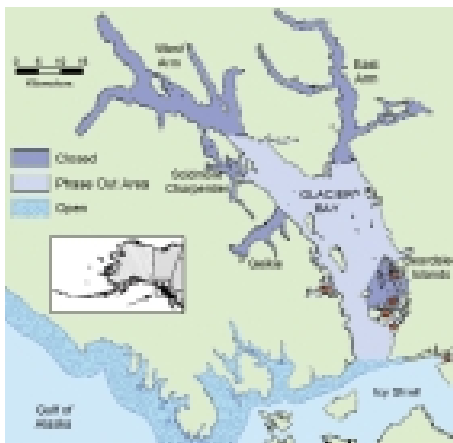


Figure 1: The open, closed, and phase-out areas for commercial fishing in Glacier Bay National Park and Preserve. The red stars represent study locations for the long-term study monitoring changes in the Dungeness crab population before and after commercial fishing.

Left: There has been a dramatic shift in the size of male Dungeness crabs following the closure of commercial fishing in Glacier Bay National Park.

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Glacier Bay National Park and Preserve is dominated by the marine waters that make up nearly one-fifth of the park's area. Since the late 1800s, the nutrient rich waters of Glacier Bay have supported highly productive commercial fisheries. Congress closed fishing in parts of Glacier Bay National Park in 1999, creating one of North America's largest marine reserves. Throughout the world, marine reserves are being promoted as effective tools for managing fisheries while simultaneously meeting marine conservation goals and maintaining marine biodiversity. Increases in individual size, density, biomass, and diversity have been demonstrated in studies of fish and invertebrates from both temperate and tropical marine reserves (Halpern 2003). Studies on the effectiveness of marine reserves at high latitudes, however, are rare. The formation of marine reserves in Glacier Bay National Park provides a unique opportunity for marine reserve research in a high latitude

ecosystem.

The legislation that closed commercial fishing in the park specifies the species and the areas that will be protected. All commercial fishing was left open in a three-mile band of water adjacent to the park's shore along Icy Strait and the Gulf of Alaska, while it was closed in Glacier Bay proper (Figure 1). Commercial fishing for Tanner crab (*Chionoecetes bairdi*) and Pacific halibut (*Hippoglossus stenolepis*) was immediately closed in five areas that vary in shape and range in size from 40 to 280 km². In the central part of the bay, fishing is being phased out through a grandfather clause, which allows fishermen to continue fishing in the central part of the bay for Tanner crab, salmon, and Pacific halibut. Over the next several decades, as fishermen retire, Glacier Bay proper will become a single large reserve for all species. For red king crabs (*Paralithodes camtschaticus*) and Dungeness crabs (*Cancer magister*) the legislation immediately closed commercial fishing in all of Glacier Bay proper.

Thus, for the immediate future, there is a reserve network of five closed areas for

Tanner crabs and halibut, while the entire bay is a reserve for red king crabs and Dungeness crabs. The network of closed areas adjacent to the open portion of the bay provides a large-scale laboratory to study marine reserve effectiveness. The marine reserves in Glacier Bay are changing the protected populations beneath the waters in ways that we are just beginning to see.

To manage the marine resources and understand marine reserve processes in Glacier Bay, the U.S. Geological Survey (USGS), with support from the National Park Service (NPS), is conducting research in order to answer some fundamental questions. First, since the reserves only protect the animals that reside within the boundaries of the protected area, we need to know the distribution and abundance of resources in each reserve. Secondly, it is important to understand how animals are moving in relation to the reserve boundaries and how much time they are spending in the protected areas. If animals are spending a significant portion of time inside the reserves, then we may start to observe some of the population changes,

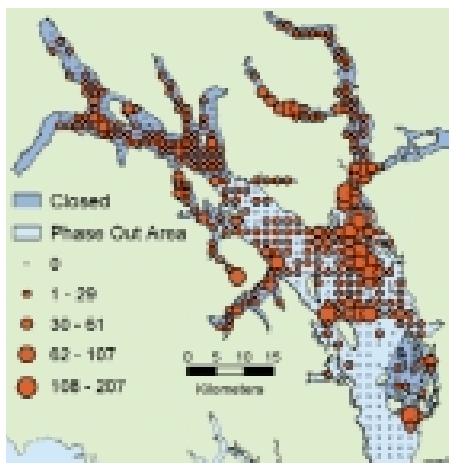


Figure 2: The catch per pot (or Catch-Per-Unit-Effort) of Tanner crabs throughout Glacier Bay.

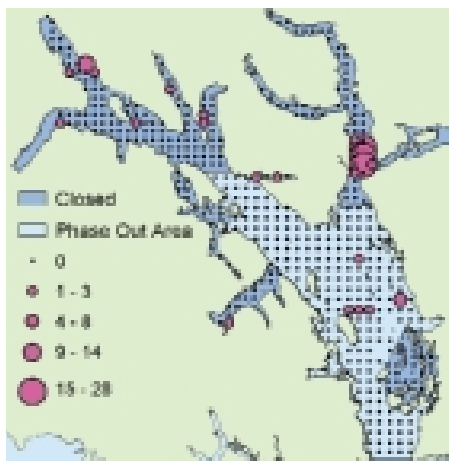


Figure 3: The catch per pot (or Catch-Per-Unit-Effort) of red king crabs throughout Glacier Bay.

such as higher abundance, that have been demonstrated in protected areas in other parts of the world.

Distribution and Abundance of Fisheries Resources in Reserves

In 1999 researchers conducted a pot survey to determine the distribution and relative abundance of Dungeness crabs throughout Glacier Bay. Although Dungeness crabs occurred throughout the park, they were very rare in the northern portion of the bay (Taggart *et al.* 2003). In the summer of 2002, researchers systematically sampled for Tanner and red king crabs throughout Glacier Bay. Sampling occurred on a one mile (1.6 km) grid blanketing the entire bay. From this sampling, estimates of the relative abundance and size frequency of the crabs inside and outside of the newly created reserves were made. Tanner crabs were widely distributed and their density was approximately equal in the closed and open areas (Figure 2). On the other hand, their distribution varied widely between protected areas; the majority of the Tanner crabs in the protected areas were in two reserves. In addition, two of the reserves had areas where juvenile Tanner crabs were abundant and thus might be potential nursery areas. In contrast to Tanner crabs, red king crabs were highly aggregated, and 73% were in a small part of a single reserve (Figure 3).

These studies illustrate that basic systematic sampling could provide vital information on where future marine reserves should be located and that reserves in close proximity to each other may have very different relative abundances of animals. Knowing there are areas with high relative

abundance inside the reserve boundaries is the first step. The next step is to determine the movements of the population in relation to the reserve boundary.

Tanner and King Crab Movement in Marine Reserves

We have initiated a research program to measure how often breeding adults enter and leave the protected areas. Our long-term vision is to simultaneously measure the transfer rate among multiple reserves and the adjacent area remaining open to commercial fishing. Red king crabs, Tanner crabs, and Pacific halibut will be sonic-

tagged within each of the reserve areas and the area open to fishing, and their movements will be detected by strings of submersible data loggers that create acoustic gates along the reserve boundaries.

In September 2002, we initiated the research by tagging 21 Tanner crabs and 16 king crabs in the East Arm reserve and installing a string of data loggers along the boundary. The data loggers are recording tagged animals that move across the reserve border. We have relocated tagged crabs every two to three months since being released by visiting a series of grid stations and systematically searching with underwa-



A USGS researcher releases a tagged king crab into the East Arm marine reserve in Glacier Bay National Park.

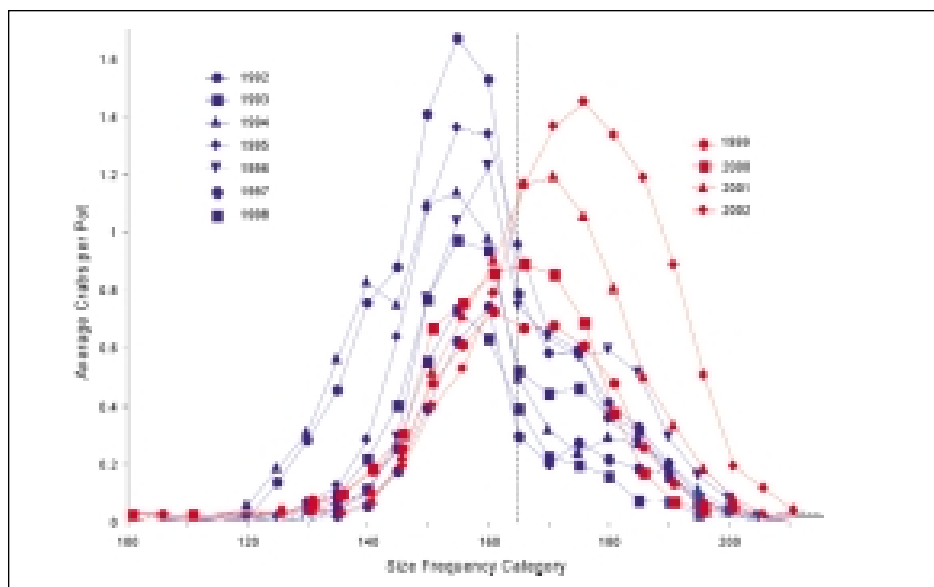


Figure 4: Average size abundance distribution for male Dungeness crab at all sites closed to commercial fishing. Each line represents a year from 1992 to 2002; blue lines are years before commercial fishing closed, and the red lines are the years after fishing closed. the dashed line shows the legal size limit (165mm) for male Dungeness crab.

ter hydrophones. Tanner crabs have shown large variation in the distance that they move. A few individuals have been relocated in the same area, but one male has traveled at least 32.5 km since it was released. The king crabs were highly aggregated when they were tagged, and they have

tended to move as a group. To date, three of the male Tanner crabs have moved across the reserve boundary, and one male and one female king crab have been located on the boundary.

We will continue to track these crabs over the next two years to estimate how much time the population spends in the reserve and determine the transfer rate across the boundary. This study will enable us to evaluate the effectiveness of the East Arm marine reserve and develop predictions about long-term changes in the Tanner and king crab population demographics inside the reserve. If the transfer rate is low, then we would expect to see increases in body size and or population abundance in the reserve.

Knowing there are areas with high relative abundance inside the reserve boundaries is the first step. The next step is to determine the movements of the population in relation to the reserve boundary.



Researchers attach a sonic tag to a Tanner crab in order to study the movement of animals inside a marine reserve in Glacier Bay National Park.



The number and size of male Dungeness crabs increased dramatically after the 1999 closure of Glacier Bay to commercial fishing.

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Changes in size of Dungeness crab after fishing closure

In anticipation of commercial fishery closures, scientists from the U.S. Geological Survey, the University of Alaska Fairbanks, and the National Marine Fisheries Service initiated a study in 1992 to document changes in the population structure of Dungeness crabs. Study sites were selected both inside and outside the proposed closure areas and sampled with commercial pots and scuba transects (Figure 1). Since 1992, we have collected seven years of pre-closure and four years of post-closure data.

After the 1999 closure of Glacier Bay to commercial fishing, the number and size of male Dungeness crabs increased dramatically (Taggart *et al. In Press*) (Figure 4). Harvest regulations allow only large male Dungeness crabs to be removed by the fishery. Therefore, one would expect changes to occur more quickly among the male crab population. During the pre-closure phase of the study, the number of male crabs over 165 mm (legal size) was relatively small compared to the number of sub-legal sized males. After the fishery closure, the number of male crabs over 165 mm began increasing, and by 2000, the number of crabs larger than 170 mm exceeded the highest abundance we had recorded during any of the 7 pre-closure years. This trend continued, and in each subsequent year since the closure, the number and size of male crabs increased. In contrast, at a control site outside of the park that is still open to commercial fishing, there was not a large shift in the size of male crabs. At

all sites, female and sub-legal sized male crabs, the portions of the population not directly targeted by commercial fishing, did not increase in size or abundance following the closure.

Our data demonstrate that a marine reserve can markedly increase the size of male Dungeness crabs. Fisheries that remove most of the large individuals from a population can select against genotypes that promote fast growth (Reznick *et al.* 1990), and slower growth can reduce productivity of fisheries (Conover and Munch 2002). If reserves protect adult animals so they have the opportunity to grow to a larger size, and there is gene exchange between the reserve and the adjacent area,

the genetic consequences of commercial fishing could potentially be mitigated by strategically located marine reserves (National Research Council 2001; Trexler and Travis 2000). The results of our research in Glacier Bay support the concept that marine reserves could help maintain genetic diversity in Dungeness crabs and other crab species subjected to size limit fisheries.

Implications

Controlled experiments testing the impact of human exploitation on the population structure of marine species are rare and even more unusual for crustaceans. Closures of fisheries are usu-

ally prompted by major declines in the abundance of the harvested species resulting in the collapses of the fishery (Jackson *et al.* 2001). In Alaska, such closures for crustaceans normally remain in effect only until there is evidence that the stocks are rebounding (Orensanz *et al.* 1998); so there are limited opportunities to compare changes in the populations of a closed area with nearby populations still being exploited. The ongoing marine reserve research in Glacier Bay will provide valuable information to managers, scientists, and the public to evaluate the utility of reserves as a management tool for solving local, national, and global marine conservation issues.

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REFERENCES

- Conover, D.O. and S.B. Munch. 2002. *Sustaining fisheries yields over evolutionary time scales.* Science 297:94-96.
- Halpern, B.S. 2003. *The impact of marine reserves: do reserves work and does reserve size matter?* Ecological Applications 13:S117-S137.
- Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R.R. Warner. 2001. *Historical overfishing and the recent collapse of coastal ecosystems.* Science 293:629-638.
- National Research Council. 2001. *Marine protected areas: tools for sustaining ocean ecosystems.* National Academy Press, Washington, D.C.
- Orensanz, J.M., J. Armstrong, D. Armstrong, and R. Hilborn. 1998. *Crustacean resources are vulnerable to serial depletion - the multifaceted decline of crab and shrimp fisheries in the greater Gulf of Alaska.* Reviews in Fish Biology and Fisheries 8:117-176.
- Reznick, D.A., H. Bryga, and J.A. Endler. 1990. *Experimentally induced life-history evolution in a natural population.* Nature 346:357-359.
- Taggart, S.J., P.N. Hooge, J. Mondragon, E.R. Hooge, and A.G. Andrews. 2003. *Living on the edge: the distribution of Dungeness crab, Cancer magister, in a recently deglaciated fjord.* Marine Ecology Progress Series 246:241-252.
- Taggart, S.J., T.C. Shirley, C.E. O'Clair, and J. Mondragon. In Press. *Dramatic increase in the relative abundance of large male Dungeness crabs, Cancer magister, following closure of commercial fishing in Glacier Bay, Alaska.* Proceedings of the American Fisheries Society.
- Trexler, J.C. and J. Travis. 2000. *Can marine protected areas restore and conserve stock attributes of reef fishes?* Bulletin of Marine Science 66:853-873.